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What role does the environment play in language development?

Exploring the associations among socioeconomic status, parent language input, and language skills in school-aged children with autism

Meredith Pecukonis[a], Lindsay Butler[b,c], and Helen Tager-Flusberg[a]

[a]Department of Psychological & Brain Sciences
Boston University
100 Cummington Mall
Boston, MA 02155

[b]Department of Speech, Language & Hearing Sciences
University of Connecticut
2 Alethia Drive, U-1085
Storrs, CT 06269

[c]Institute for the Brain & Cognitive Sciences
University of Connecticut
337 Mansfield Road, Unit 1272
Storrs, CT 06269

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Lay Summary

This study investigated the associations among measures of socioeconomic status (SES), the quantity and quality of language produced by parents and their autistic school-aged children during home-based dyadic parent-child interactions, and children's expressive and receptive language skills. We found that SES was not associated with children's language skills, although annual household income, one measure of SES, was positively associated with the quantity and quality of language used by parents during the parent-child interactions. Parents of autistic children with higher expressive language skills used longer utterances during the parent-child interactions, which suggests that 1) parents are adjusting the length of their utterances to match their child's current expressive language skills, and/or 2) using longer utterances when interacting with autistic children may support their expressive language development.

Abstract

Language development in children with autism is influenced by proximal (e.g., parent language input) and distal (e.g., socioeconomic status) environmental constructs. Studies have found that "rich and responsive" parent language input supports autistic children's language development, and recent work has reported positive associations between measures of socioeconomic status (SES) and child language skills. However, little is known about how these proximal and distal environmental constructs interact to shape language development in autism. In a sample of 74 autistic school-aged children, the present study investigated the associations among measures of SES, the quantity and quality of language produced by parents and children during home-based dyadic parent-child interactions, and children's expressive and receptive language skills. Results showed that annual household income was positively associated with parent number of total words (NTW), parent number of different words (NDW), and parent mean length of utterance (MLU), while neither parent education level nor annual household income were significantly associated with measures of child language skills. Parent MLU was positively associated with child MLU and child expressive language skills. Findings suggest that annual household income may influence both the quantity and quality of parent language input, and that parent MLU, a qualitative measure of parent language input, may play a particularly important role in shaping autistic children's expressive language development. Future research should study longitudinal associations among SES, parent language input, and child language skills, as identifying environmental predictors of language skills in autism may facilitate the creation of more effective interventions that support language development.

Keywords: socioeconomic status, parent language input, child language skills, natural language sample

What role does the environment play in language development? Exploring the associations among socioeconomic status, parent language input, and language skills in school-aged children with autism

According to Bronfenbrenner's bioecological theory, development is influenced by a variety of constructs or "processes" within a child's environment (Bronfenbrenner, 2001). The proximal environment, which immediately surrounds the child, includes direct interactions with parents, family members, caregivers, and peers (Bronfenbrenner & Morris, 2006). In contrast, the distal environment includes constructs within the broader community, such as politics, culture, and the economy (Bronfenbrenner & Morris, 2006). Within the context of language development, a commonly studied construct within the proximal environment is "parent language input," which is defined as the quantity and quality of language that children are exposed to at home (Rowe & Weisleder, 2020). Within the distal environment, a commonly studied construct is socioeconomic status or "SES." SES is a complex construct composed of different variables, including parent education level and annual household income (Ensminger & Fothergill, 2003). Several studies have documented positive associations between proximal and distal environmental constructs and language skills in neurotypical children (Anderson et al., 2021; Letourneau et al., 2013). Indeed, parents who use a larger number of different words and longer utterances during parent-child interactions, attain education beyond high school, and make more money tend to have children with stronger language skills (Hoff, 2006). More research, however, is needed to determine how proximal and distal environmental constructs relate to language skills in children with developmental disabilities, such as autism.

Quantity and quality of parent language input and child language skills in autism

A handful of studies to date have demonstrated that parent language input is positively associated with language skills in children with autism and toddlers at elevated likelihood for

autism (e.g., Bang & Nadig, 2015; Choi et al., 2020; Fusaroli et al., 2019; Romeo et al., 2022). These studies measured parent language input in a variety of ways, including number of total words produced (i.e., NTW or word tokens), which is a quantitative measure of linguistic volubility, number of different words produced (i.e., NDW or word types), which is a qualitative measure of lexical diversity/expressive vocabulary, and mean length of utterance (MLU), which is a qualitative measure of grammatical complexity (Bottema-Beutel & Kim, 2021). Researchers have found that these measures of parent language input are positively associated with children's concurrent and longitudinal language skills, as measured by standardized behavioral assessments, parent-report measures, and natural language sampling methods (Bang & Nadig, 2015; Choi et al., 2020; Fusaroli et al., 2019; Romeo et al., 2022). For example, studies conducted with autistic children and toddlers at elevated likelihood for autism have shown that parent MLU is a positive predictor of child MLU measured 4 months later (in 24 to 60 month olds; Fusaroli et al., 2019) and child verbal developmental quotient scores (in 12 to 24 month olds; Choi et al., 2020) and expressive vocabulary scores (in 50 to 85 month olds; Bang & Nadig, 2015) measured 6 months later. Parent NTW and parent NDW have also been positively linked to children's expressive language skills (in 18 to 24 month olds; Romeo et al., 2022; although see Bang & Nadig, 2015 and Choi et al., 2020). These positive associations between parent language input and child language skills seem to be bi-directional, as early measures of child language skills have been shown to positively predict parent NDW (Fusaroli et al., 2019) and parent MLU (Choi et al., 2020) later in development. In all, findings from these studies suggest that parent language input may have a positive impact on language development in autism, and that parents of autistic children may be adapting their language input based on their child's language skills. These findings are similar to what has been reported in the literature on neurotypical children

(Anderson et al. 2021), suggesting that the quantity and quality of language that children are exposed to at home may help shape language development for children with and without autism (also see Swanson et al., 2020 and Rowe & Weisleder, 2020 for review). Because many of these studies were conducted with toddlers at elevated likelihood for autism, further research is needed to determine whether the association between parent language input and child language skills differs in older autistic children as they enter school age.

SES and child language skills in autism

To date, only three published studies have explicitly investigated the association between SES and language skills in autism; these studies have reported mixed findings (Olson et al., 2021; Pecukonis et al., 2022; Pecukonis et al., 2024). Pecukonis and colleagues (2022) found that maternal education level, one measure of SES, was a positive predictor of verbal developmental quotient scores in 36 month old toddlers at elevated likelihood for autism. Similarly, a study conducted by Olson and colleagues (2021) found positive associations between maternal education level and expressive and receptive language skills in 15 to 64 month old autistic children, as measured by parent-report and behavioral assessment. Annual household income, another measure of SES, was also positively associated with child expressive language skills, as measured by behavioral assessment only (Olson et al., 2021). In contrast to Pecukonis et al. (2022) and Olson et al. (2021), another study by Pecukonis and colleagues (2024) reported that maternal education level was not significantly associated with 23 to 61 month old autistic children's language skills, as measured by parent-report and behavioral assessment. Taken together, these findings indicate that SES may be positively associated with language skills in autism, although the significance of this association appears to vary depending on how SES and child language skills are measured. Thus, further research is needed to understand how SES, as

measured by parent education level and annual household income, relates to autistic children's expressive and receptive language skills.

The interaction between SES, parent language input, and child language skills in autism

Bronfenbrenner argued that constructs within a child's distal environment may influence development by altering constructs within their proximal environment (Bronfenbrenner, 2001; Bronfenbrenner & Morris, 2006). Research conducted with neurotypical children provides evidence in support of this argument, demonstrating that measures of parent language input mediate the association between measures of SES and child language skills (e.g., Huttenlocher et al., 2010; Hoff, 2003; Vernon-Feagans et al., 2013). More specifically, studies have shown that parent education level and annual household income predict parent MLU (Hoff, 2003; Vernon-Feagans et al., 2013) and parent NDW (Huttenlocher et al. 2010), which in turn predict child language skills, as measured by behavioral assessment and natural language sampling methods.

Less is known about the associations among measures of SES, parent language input, and child language skills in autism. Surprisingly, most studies examining the association between measures of parent language input and child language skills in autism have failed to control for measures of SES in their analyses (e.g., Bang & Nadig, 2015; Fusaroli et al., 2019). Similarly, studies exploring the association between measures of SES and autistic children's language skills have not included any measures of parent language input (Olson et al., 2021; Pecukonis et al., 2022; Pecukonis et al., 2024). Thus, our current understanding of how these proximal and distal environmental constructs interact to shape language development in autism is limited.

To the best of our knowledge, only one study to date has explored the associations among SES, language input received at home, and child language skills in autism (Swanson et al., 2019). In this longitudinal study of toddlers at elevated likelihood for autism, Swanson and

colleagues (2019) used multi-day LENA recordings to characterize the quantity of language produced by parents and other adults in the home. This study found that measures of SES and language input were significantly and positively associated with child language skills. More specifically, the NTW (i.e., word tokens) used by adults in the home when children were 15 months of age mediated the association between SES, as measured by parent education level, and child language skills at 24 months of age, as measured by behavioral assessment. Despite the importance of this study, Swanson et al. (2019) did not include annual household income as a measure of SES, nor did they include other commonly studied qualitative measures of language input (i.e., MLU and NDW). Therefore, we do not currently know how these additional measures of SES and language input interact to shape language development, particularly in older autistic children. Further studying the associations among measures of SES, parent language input, and child language skills in autism will provide insight into the possible mechanisms through which the distal environment shapes language development by way of the proximal environment in this clinical population.

Present study

The present study utilized a sample of 74 school-aged autistic children (4 to 8 years old) to investigate the associations among measures of SES (parent education level and annual household income), the quantity and quality of language produced by parents and children during home-based dyadic parent-child interactions (NTW, NDW, and MLU), and children's expressive and receptive language skills, as measured by parent-report. Using structural equation modeling (SEM), we examined the bivariate associations between observed variables of interest while statistically controlling for all other variables, as well as covariates (child age and autism traits), within a single model. We also explored the indirect associations between measures of SES and

child language skills to gain further insight into whether distal environmental constructs (i.e., SES) might influence autistic children's language skills through proximal environmental constructs (i.e., parent language input). Based on previous literature, we hypothesized that our measures of SES and parent language input would be positively associated with our measures of child language skills (Bang & Nadig, 2015; Choi et al., 2020; Fusaroli et al., 2019; Olson et al., 2021; Pecukonis et al., 2022; Romeo et al., 2022). We also hypothesized that our measures of parent language input would significantly mediate the associations between our measures of SES and child language skills (Huttenlocher et al., 2010; Hoff, 2003; Vernon-Feagans et al., 2013).

Methods

Sample

N=105 English-speaking children with a community diagnosis of autism spectrum disorder (ASD) were enrolled in this remote-based study carried out in the United States between December 2020 and November 2021. Out of the 105 families enrolled, 13 were recruited through advertisements on social media and 92 were recruited through the Simons Foundation Powering Autism Research for Knowledge (SPARK) research match registry (Feliciano et al., 2018). SPARK is a national genotyping project for autism spectrum disorder that recruits families primarily from academic medical centers in the United States. Once families enroll in SPARK, they are given the opportunity to enroll in approved research studies through SPARK's online research registry. The SPARK cohort has been shown to have high validity for autism diagnosis (98.8% agreement; Fombonne et al., 2021).

Out of the 105 children enrolled, 31 were excluded from the present sample. 13 did not complete the study after enrollment, 13 had missing data on either the Vineland Adaptive Behavior Scales or the parent-report demographics form, 2 had parent-child interactions that

could not be transcribed due to insufficient audio quality, and 3 had parent-child interactions that were not dyadic (i.e., more than two conversational partners were present). The final sample consisted of *N*=74 children (15 females, 59 males) who had complete data for all variables of interest. See Table 1 for a summary of sample sociodemographics and descriptive statistics. All study procedures were reviewed and approved by the Institutional Review Board at Boston University.

Measures

Parent-report demographics form. Sociodemographic information about each child and their family was collected using an online parent-report demographics form. For the present study, SES was measured using two variables gathered from this demographics form: the highest education level attained by the parent who was the child's primary caregiver (95.90% mothers, 4.10% fathers) and their family's annual household income. Annual household income could not be adjusted for cost of living or size of household, given that income data were collected using an ordinal scale from 1 to 11 (see Table 1 for categorical descriptions) rather than exact income values. Parent education level data were collected using an ordinal scale from 1 to 6 and converted to years of education for analyses (less than high school=10 years, completed high school=12 years, vocational or technical school or some college=14 years, completed college=16 years, professional or doctoral training beyond college=18 years).

Parent-child interactions. Dyadic parent-child interactions were conducted remotely within each child's home and recorded using Zoom. Parents were instructed to play with their child for 15 minutes using two to four activities that they selected to hold their child's attention and promote communication. Activities selected by parents included conversation, cooking/baking, coloring/art, educational activities, figure play, games/puzzles, manipulatives,

motor activities, screentime, sensory activities, shared book reading, singing/reciting, and snack (Butler et al., 2022). These parent-child interactions served as natural language samples during which we assessed the language used by both the parent and the child within their everyday environment (Barokova & Tager-Flusberg, 2020).

Recordings of the parent-child interactions were transcribed and processed using the systematic analysis of language transcripts software (SALT; Miller & Iglesias, 2012). Transcription was completed by four trained researchers, including one postdoctoral researcher/speech language pathologist, one graduate student, and two undergraduate students. Transcription training involved 10 hours of self-paced online SALT training modules followed by supervised practice until a 90% reliability on communication units and morpheme segmentation was reached. Following SALT guidelines, spoken utterances were segmented into communication units, which were defined as an independent clause with its modifiers. A trained researcher first transcribed all utterances and marked bound morphemes according to SALT guidelines. Then, a second trained researcher reviewed the transcript and the recording of the parent-child interaction to identify any errors in transcription. Discrepancies were settled by the two researchers reaching a consensus, in accordance with SALT guidelines. In the rare case that a consensus could not be reached, the word or utterance in question was marked as unintelligible to avoid inflating the number of intelligible words spoken.

Once transcripts were finalized, SALT was used to obtain parent and child language variables. Parent language input was measured using three variables that were obtained from the processed transcripts: number of total words produced by the parent per minute (parent NTW), which is a quantitative measure of linguistic volubility, number of different words used by the parent per minute (parent NDW), which is a qualitative measure of lexical diversity/expressive

vocabulary, and mean length of utterance in morphemes produced by the parent (parent MLU), which is a qualitative measure of grammatical complexity. Child language skills were measured using similar variables that were obtained from the processed transcripts: number of total words produced by the child per minute (child NTW), number of different words produced by the child per minute (child NDW), and mean length of utterance in morphemes produced by the child (child MLU). Child language variables included utterances that were produced spontaneously, excluding echolalia, scripted recitation, neologisms, and idiosyncratic speech (see Butler et al., 2022 for more information about transcription procedures). 8 children in the current sample were considered non-speaking, as they produced no spoken words and had a MLU of zero during the parent-child interactions.

Vineland adaptive behavior scales. Child language skills were also measured using the Vineland Adaptive Behavior Scales-Third Edition (VABS; Sparrow, Cicchetti, & Saulnier, 2016). The VABS is a standardized parent-report measure that assesses various domains of children's adaptive functioning, including communication, motor, socialization, and daily living skills. Parents completed the VABS in a semi-structured interview format with a trained researcher over Zoom. VABS expressive communication (EC) raw scores and receptive communication (RC) raw scores were used in analyses to capture children's expressive and receptive language skills, respectively.

Social communication questionnaire. Parents completed the second edition of the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003), a brief parent-report questionnaire that assesses autism traits. Higher SCQ scores indicate greater "severity" of autism traits. Child SCQ scores were included as a covariate in analyses to control for children's autism traits.

Planned analyses

We first conducted Spearman's zero-order correlation analyses to examine the associations among all variables of interest, including covariates. We then conducted Spearman's partial correlation analyses controlling for child age and child SCQ scores. Last, we constructed a fully saturated structural equation model (SEM) in Mplus (version 8.5; Muthén & Muthén, 2017). Using a fully saturated model allowed us to examine the bivariate associations between observed variables of interest while statistically controlling for all other potentially confounding variables within a single model. Robust maximum likelihood estimation was used to account for non-normally distributed data (Finney & DiStefano, 2006). The model included direct paths between our two SES variables (parent education level and annual household income), our three parent language variables (parent NTW, parent NDW, and parent MLU), and two of our child language variables (VABS EC scores and VABS RC scores). Only VABS EC scores and RC scores were included in the model because these scores provided a measure of child language skills that was collected independently from the parent-child interactions. Child age and SCQ scores were also included as covariates in the model. SES variables, parent language variables, child language variables, and covariates were allowed to covary with each other.

Results

Spearman's correlation analyses

Spearman's zero-order and partial correlations are presented in Table 2. When controlling for child age and child SCQ scores, annual household income was significantly and positively correlated with all three parent language variables (parent NTW: r_s=.256, p=.030; parent NDW: r_s=.306, p=.009; parent MLU: r_s=.236, p=.046), but not significantly correlated with any child language variables (ps≥.226). Parent education level was not significantly correlated with any

parent language variables (*p*s≥.589) or child language variables (*p*s≥.052), although the association between parent education level and child VABS RC scores was marginally significant (*p*=.052). Parent MLU was significantly and positively correlated with child MLU (r_s=.283, *p*=.016) and child VABS EC scores (r_s=.232, *p*=.050). All other partial correlations between parent language variables and child language variables were non-significant (*p*s≥.064). All parent language variables were significantly and positively correlated with each other (r_ss=.564–.866, *p*s<.001), as were all child language variables (r_ss=.253–.990, *p*s≤.032).

SEM

Unstandardized parameter estimates from the SEM are presented in Table 3. Looking first at the associations between measures of SES and parent language input, the model demonstrated that annual household income was significantly and positively associated with parent NTW (*b*=1.978/β=.312, *SE*=.670, *p*=.003), parent NDW (*b*=.436/β=.357, *SE*=.160, *p*=.006), and parent MLU (*b*=.078/β=.277, *SE*=.037, *p*=.036). Parent education level was not significantly associated with any of the parent language variables (*p*s≥.158). Looking next at the associations between measures of SES and child language skills, annual household income was not significantly associated with child VABS EC scores or RC scores (*p*s≥.566). Parent education level was also not significantly associated with child VABS EC scores or RC scores (*p*s≥.108). Looking last at the associations between measures of parent language input and child language skills, parent MLU was significantly and positively associated with child VABS EC scores (*b*=7.905/β=.257, *SE*=3.072, *p*=.010), but not with child VABS RC scores (*p*=.573). Parent NTW and parent NDW were not significantly associated with child VABS EC scores or RC scores (*p*s≥.530).

Looking at the associations between co-variates and parent and child language variables, child age was significantly and negatively associated with parent NTW (*b*=-.397/β=-.271, *SE*=.157, *p*=.012), but not with parent NDW, parent MLU, child VABS EC scores, or child VABS RC scores (*p*s≥.074). Child SCQ scores were significantly and negatively associated with parent NDW (*b*=-.125/β=-.226, *SE*=.060, *p*=.036) and parent MLU (*b*=-.042/β=-.328, *SE*=.013, *p*=.001), but not significantly associated with parent NTW (*p*=.127). Child SCQ scores were also significantly and negatively associated with child VABS EC scores (*b*=-1.817/β=-.463, *SE*=.432, *p*<.001) and VABS RC scores (*b*=-1.582/β=-.644, *SE*=.248, *p*<.001).

When examining the specific indirect associations between measures of SES and child language skills, the model demonstrated that the specific indirect effect of annual household income on child VABS EC scores via parent MLU was marginal yet non-significant (*b*=.619/β=.071, *SE*=.364, *p*=.090). All other specific indirect associations were non-significant (*p*s≥.548). Overall, the model explained 38.7% of the variance in child VABS EC scores and 49.3% of the variance in child VABS RC scores. Significant direct associations, covariances, and residual variances are depicted in Figure 1.

Discussion

The present study aimed to identify the proximal and distal environmental predictors of language skills in school-aged children with autism. More specifically, we investigated the associations among measures of SES, the quantity and quality of language produced by parents and children during home-based dyadic parent-child interactions, and children's expressive and receptive language skills. We found that annual household income, but not parent education level, was significantly and positively associated with quantitative and qualitative measures of parent language input, including parent NTW, parent NDW, and parent MLU. We also found

that parent MLU was significantly and positively associated with child MLU and child expressive language skills. Contrary to our hypotheses, neither parent education level nor annual household income were significantly associated with any measures of child language skills. Furthermore, our model showed no evidence of significant mediation between measures of SES and child language skills via measures of parent language input. Findings suggest that annual household income may influence the quantity and quality of parent language input that autistic children receive at home, and that parent MLU, a qualitative measure of parent language input, may play a particularly important role in shaping autistic children's expressive language development.

Annual household income is positively associated with quantitative and qualitative measures of parent language input

Annual household income was significantly and positively associated with all measures of parent language input (parent NTW, parent NDW, and parent MLU). This finding, which highlights the interconnectedness of constructs within the distal and proximal environments, is consistent with numerous studies that have documented differences in parent language input based on SES in neurotypical children (Rowe, 2018). Unlike annual household income, parent education level was not significantly associated with any measures of parent language input in the present study. These findings align with previous studies that reported non-significant associations between maternal education level and measures of parent language input (NTW, NDW, MLU) in samples of children with autism (Barokova & Tager-Flusberg, 2024) and toddlers at elevated likelihood for autism (Choi et al., 2020). While annual household income and parent education level are often correlated with each other, as they were in the present study, they are distinct measures of SES, and as stated by Rowe (2018), they "may predict variation in

parents' input through distinct processes and mechanisms" (p.124). For instance, the quantity and quality of parent language input could be influenced by other constructs within the proximal environment that are often associated with reduced household income and thus economic hardships, such as increased parental stress (Pierce, Reilly, & Nelson, 2021; although see Hart et al., 2023), increased household chaos (Seidler & Ritchie, 2018), lack of access to learning and literacy resources at home (Jiang, Lau, & Tan, 2023), or other structural constraints (Ellwood-Lowe, Foushee, & Srinivasan, 2022). While current findings suggest that the quantity and quality of parent language input varies based on annual household income, further research is needed to improve our understanding of *why* annual household income is associated with parent NTW, parent NDW, and parent MLU in children with autism. Additionally, future studies should include more inclusive measures of language input (e.g., language input from all adults in the home, overheard speech), as these measures may also vary based on SES (Sperry, Sperry, & Miller, 2019).

Measures of SES are not significantly associated with measures of child language skills

Contrary to our hypotheses, we found no significant associations between our measures of SES and our measures of child language skills (although note that the partial correlation between parent education level and child VABS RC scores was marginally significant). This finding was surprising given that previous studies have documented significant and positive associations between measures of SES (maternal education level and/or annual household income) and expressive and receptive language skills in children with autism (Olson et al., 2021; Pecukonis et al., 2022; although see Pecukonis et al., 2024). One explanation for these contrasting findings is that SES may only relate to certain aspects of child language skills that are captured by behavioral assessments, such as the Mullen Scales of Early Learning (MSEL), given

that both Pecukonis et al. (2022) and Olson et al. (2021) used this assessment to measure child language skills. However, Olson and colleagues (2021) also used the VABS to measure child language skills and found a significant, positive association between maternal education level and VABS communication domain scores. Because we included VABS expressive and receptive communication scores separately in our analyses rather than VABS communication domain scores (also see analyses in Pecukonis et al., 2024), which capture expressive, receptive, *and* written communication scores, it is possible that written communication scores were driving the significant findings reported in Olson et al. (2021). Differences in sample characteristics, such as child age and inclusion/exclusion of neurotypical participants, distribution and range of SES variables, and statistical methods used may also contribute to varying findings across studies.

While the present study did not find evidence of a significant association between measures of SES and child language skills, this does not necessarily mean that the distal environment has no influence on language development in autism. Rather, it suggests that there are other constructs that have a stronger, more direct influence on autistic children's language development. These constructs may exist within the distal or proximal environments, or they may be child internal traits or behaviors. For instance, the present study found that child SCQ scores, a measure of autism traits, were significantly associated with all child language variables and explained a large proportion of the variance in child language skills. This finding suggests that the SCQ captures some trait or behavior within the autism phenotype that impacts language development. Other constructs that have been shown to have a strong influence on language development in autism, but were not measured in the present study, include neurobiological differences (Cermak et al., 2022; Groen et al., 2008), broader cognitive abilities (i.e., NVIQ; Magiati, Tay, & Howlin, 2014), and access to early intervention (Hampton & Kaiser, 2016).

Future research should continue to explore how internal traits and behaviors interact with constructs within the distal and proximal environments to shape language development in autism.

Parent MLU is positively associated with child MLU and child expressive language skills

Parent MLU was significantly and positively associated with child MLU and child expressive language skills, as measured by VABS EC scores. These findings align with previous studies of autistic children and toddlers at elevated likelihood for autism which demonstrated that parent MLU was a positive predictor of child MLU (Fusaroli et al., 2019), child verbal developmental quotient scores (Choi et al., 2020), and child expressive vocabulary scores (Bang & Nadig, 2015). Unlike parent MLU, parent NTW and parent NDW were not significantly associated with any of our measures of child language skills. Previous studies have similarly reported non-significant associations between these two measures of parent language input (parent NTW and parent NDW) and children's verbal developmental quotient scores (Choi et al., 2020) and expressive vocabulary scores (Bang & Nadig, 2015). However, while previous research has reported significant associations between parent and child language variables measured at the same time point (i.e., NTW, NDW, and MLU; Fusaroli et al., 2019), partial correlations between parent NTW and child NTW, and between parent NDW and child NDW, were non-significant in the present study (although note that the zero-order correlation between parent NDW and child NDW was significant). Because children in Fusaroli et al. (2019) were younger than children in the present study, our non-significant findings suggest that "linguistic matching" of NTW and NDW in parent-child dyads may not occur for older children with autism as they enter school age. Indeed, parents of school-aged autistic children with lower language skills may be producing higher NTW and NDW as a strategy to support their child's delayed

language development. We did, however, find a positive association between parent MLU and child MLU that remained significant when controlling for child age and autism traits. This positive association between parent MLU and child MLU was also reported in Fusaroli et al. (2019). Taken together, these findings suggest that linguistic matching of MLU remains an important feature of parent-child interactions throughout early and middle childhood.

Parent MLU seems to be one of the strongest predictors of language skills in autistic children when compared to other measures of parent language input. Romeo and colleagues (2022) studied the association between measures of parent language input (NTW, NDW, and MLU) at 18 months and child language skills at 24 months in a sample of toddlers at elevated likelihood for autism. While all three measures of parent language input were significantly correlated with children's VABS EC scores, when entered together in a regression model, parent MLU was the only measure of parent language input to remain a significant predictor of child language skills (Romeo et al., 2022). Sandbank and Yoder (2016) conducted a meta-analysis examining the association between parent MLU and language skills in children with various developmental disabilities and found a positive association between parent MLU and child language skills that was strongest for studies that included autistic children in their samples. Placing the present cross-sectional study within the context of the broader literature, which includes longitudinal studies, our findings provide further evidence to suggest that parent MLU supports expressive language development in school-aged children with autism. Parents who produce longer utterances are providing linguistic input with greater grammatical complexity, which may in turn bolster children's expressive language development.

The positive association found between parent MLU and child MLU and expressive language skills may also indicate that parents are adjusting their language input, specifically the

length of their utterances, to match their child's current language skills. For instance, if a parent perceives their child to have difficulties using spoken language, then they may use shorter utterances to make their verbal message easier for their child to understand and respond to. Parents may also be adjusting the length of their utterances based on the severity of their child's autism traits, given that we also found significant associations between parent MLU and child SCQ scores. Previous research has argued that the association between parent language input and child language skills is bi-directional (e.g., Choi et al., 2020; Fusaroli et al., 2019). In a sample of toddlers at elevated likelihood for autism, Choi and colleagues (2020) found that child verbal developmental quotient scores at 18 months positively predicted parent MLU at 24 months, and that parent MLU at 18 months positively predicted child verbal developmental quotient scores at 24 months. Because the present study collected measures of parent language input and child language skills at the same time point, we cannot draw conclusions about the direction of causality between parent MLU and child language skills. While more longitudinal work is needed to determine whether this bi-directional association between parent language input and child language skills continues into the school-aged years, the evidence to date favors a bi-directional association in which the quality of parent language input influences children's language development, and children's language skills influence the quality of language that parents use during parent-child interactions.

Measures of parent language input did not mediate the association between measures of SES and child language skills

Contrary to our hypotheses, none of our measures of parent language input significantly mediated the association between our measures of SES and child language skills. We did observe an indirect association between annual household income and child VABS EC scores via parent

MLU, however, this association did not reach statistical significance. It is possible that this indirect association would be statistically significant in larger sample. Nevertheless, this finding contrasts with Swanson and colleagues (2019), who reported that the NTW used by adults in the home significantly mediated the association between parent education level and child language skills in a sample of toddlers at elevated likelihood for autism. These incongruent findings may be due to differences in methods of assessing the household language environment or sample characteristics, such as inclusion/exclusion of neurotypical children or child age. It may be that proximal and distal environmental constructs, and the interactions between these constructs, have distinct impacts on language during different periods of development (see Rowe, 2012). During the first few years of life, children are primarily exposed to language from their parents and other adult caregivers at home. But as children enter school age, they begin to receive additional language input from other individuals, such as teachers and peers. They may also gain access to resources at school that they did not previously have at home, such as school-based interventions or additional learning and literacy materials. This "widening" of the child's proximal environment during the school age years introduces additional environmental constructs that may alter the impact that SES and parent language input have on language development. It is also important to note that Swanson and colleagues (2019) used a longitudinal study design, while the present study collected data at one time point, which could also be contributing to different findings between studies. Future research should continue to investigate how measures of SES and parent language input interact to shape language development in autistic individuals throughout the lifespan, prioritizing the use of longitudinal study designs.

It is likely that there are other constructs within the proximal environment, not measured in the present study, that significantly mediate the association between SES and autistic

children's language skills. Pace and colleagues (2017) outlined three mechanisms or indirect "pathways" by which measures of SES influence language development in neurotypical children – the quantity and quality of parent-child interactions, child characteristics (e.g., learning processes), and the availability of learning resources at home and within the broader community. Rowe (2018) also offered potential mediators of the association between SES and language skills in neurotypical children, including parent beliefs and knowledge about child development. While these mechanisms have been widely discussed within the context of neurotypical development, similar mechanisms may exist for children with autism and should be explored in future research.

Limitations and future directions

The present study includes limitations that should be addressed in future work. First, data were collected at one time point, and thus we cannot draw conclusions about causality or directionality between variables. Future studies should measure variables at multiple time points and utilize cross-lagged panel models, as this will clarify the directionality of associations among SES, parent language input, and child language skills. Second, the sociodemographic composition of our sample does not reflect the racial, ethnic, and socioeconomic diversity of the broader United States population, as 71% of children in our sample were White and 85% were not Hispanic or Latino. Furthermore, 88% of parents in our sample attained education beyond high school; this restricted range in parent education level may have contributed to some of our non-significant findings. These sample characteristics also notably limit the generalizability of our findings, and thus, findings reported here may not be as meaningful for children from lower SES families. Future studies should make concerted efforts to recruit a larger and more racially, ethnically, and socioeconomically diverse sample, as the association between SES and autistic

children's language skills may vary based on sample sociodemographics (Pecukonis et al., 2024). Additionally, future studies should include comparison groups of non-autistic children, including neurotypical children and children with developmental language disorders, to clarify whether the associations among SES, parent language input, and child language skills differ for clinical and non-clinical populations. Third, measures of other communication modalities (e.g., non-spontaneous speech, manual sign language, speech generating devices), in addition to broader cognitive abilities (i.e., NVIQ), should be included in future studies so that we can better understand how the environment shapes the development of communication in autism more broadly, particularly for those who are minimally verbal or non-speaking. Fourth, our measure of annual household income did not account for family size or cost of living, which could have contributed to the non-significant associations found between income and child language skills. It is crucial that future work include additional measures of SES, such as the Hollingshead index (Hollingshead, 1975; also see Cowan et al., 2012) or family ratio of income to poverty, and the household language environment, including language input from siblings and other adult caregivers (Bontinck et al., 2020), overheard speech (Luyster & Arunachalam, 2020), and language input provided by screen time and other educational media (Dong et al., 2021; Mathée-Scott & Weismer, 2022), as these environmental constructs may also impact children's language development. Lastly, while 10-20 minute long elicited natural language samples are sufficient to extract reliable language measures from children with autism (Tager-Flusberg et al., 2009), they may not capture the same features of the household language environment as all day recordings. Future studies should prioritize the collection all day recordings, which may more reliably capture the language skills of school-aged autistic children (Jones et al., 2019; Oller et al., 2010).

In conclusion, the present study demonstrates how proximal and distal environmental constructs, and the interactions between them, relate to language skills in children with autism. Findings suggest that annual household income may influence the quantity and quality of parent language input that autistic children receive at home, and that parent MLU may play a particularly important role in shaping expressive language development for school-aged children with autism. This study highlights the importance of measuring both proximal and distal environmental constructs when studying language development in autism. Future research should continue to document the longitudinal associations among measures of SES, parent language input, and child language skills, as identifying the environmental predictors of language skills in autism may support the creation of more effective interventions that ultimately support autistic children's language development.

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Table 1. Sample sociodemographics and descriptive statistics

Child age (months)	75.26 (12.50) 49.00 – 95.00
Child race	
American Indian/Alaska Native	1.40%
Asian	4.10%
Black or African American	9.50%
More than one race	9.50%
Other	1.40%
White	73.00%
Child ethnicity	
Hispanic/Latino	13.50%
Not Hispanic/Latino	85.10%
Child SCQ scores	18.58 (6.39) 3.00 – 35.00
Child VABS composite scores	59.54 (13.12) 31.00 – 84.00
Number of individuals per household	4.20 (1.45) 2.00 – 9.00
Parent education level	
Less than high school	0.00%
Completed high school	9.50%
Vocational or technical school	2.70%
Some college	18.90%
Completed college	37.80%
Professional or doctoral training beyond college	31.10%
Annual household income	
<$15,000	4.10%
$15,000-$30,000	12.20%
$30,000-$40,000	6.80%
$40,000-$50,000	10.80%
$50,000-$60,000	5.40%
$60,000-$80,000	8.10%
$80,000-$100,000	17.60%
$100,000-$125,000	17.60%
$125,000-$150,000	4.10%
$150,000-$200,000	5.40%
>$200,000	8.10%
Parent language input	
Parent NTW	52.59 (18.28) 11.20 – 114.00
Parent NDW	13.02 (3.52) 6.07 – 23.27
Parent MLU	4.09 (.81) 2.73 – 6.09

Child language skills	
Child NTW	7.01 (10.54) 0.00 – 46.67
Child NDW	2.81 (3.50) .00 – 15.53
Child MLU	1.79 (1.21) .00 – 5.94
VABS EC raw scores	46.09 (25.11) 9.00 – 95.00
VABS RC raw scores	46.80 (15.72) 9.00 – 77.00

Note: Values reflect *M* (*SD*) and range unless otherwise stated. Data on race and ethnicity is missing from *N*=1. EC: expressive communication, MLU: mean length of utterance, NDW: number of different words, NTW: number of total words, RC: receptive communication, SCQ: social communication questionnaire, VABS: vineland adaptive behavior scales.

Table 2. Zero-order and partial correlations between variables of interest and covariates

	Annual household income	Parent education level	Parent NTW	Parent NDW	Parent MLU	Child NTW	Child NDW	Child MLU	VABS EC scores	VABS RC scores	Child age	Child SCQ scores
Annual household income	1.00	-	-	-	-	-	-	-	-	-	-	-
Parent education level	.497*** (.512***)	1.00	-	-	-	-	-	-	-	-	-	-
Parent NTW	.226+ (.256*)	.038 (-.048)	1.00	-	-	-	-	-	-	-	-	-
Parent NDW	.265* (.306**)	.038 (-.007)	.871*** (.866***)	1.00	-	-	-	-	-	-	-	-
Parent MLU	.168 (.236*)	.024 (.065)	.541*** (.564***)	.646*** (.645***)	1.00	-	-	-	-	-	-	-
Child NTW	.028 (.116)	.013 (.053)	.043 (-.031)	.207+ (.127)	.340** (.216+)	1.00	-	-	-	-	-	-
Child NDW	.056 (.144)	.034 (.089)	.055 (-.001)	.231* (.167)	.339** (.219+)	.991*** (.990***)	1.00	-	-	-	-	-
Child MLU	.026 (.112)	.006 (.067)	.044 (-.006)	.195+ (.130)	.394*** (.283*)	.925*** (.906***)	.924*** (.904***)	1.00	-	-	-	-
VABS EC scores	.020 (.130)	.086 (.151)	.087 (.002)	.182 (.079)	.370*** (.232*)	.848*** (.796***)	.844*** (.799***)	.827*** (.776***)	1.00	-	-	-
VABS RC scores	-.023 (.125)	.093 (.230+)	.155 (.099)	.218+ (.116)	.336** (.143)	.502*** (.258*)	.495*** (.265*)	.491*** (.253*)	.720*** (.547***)	1.00	-	-
Child age	-.044	-.324**	-.265*	-.157	.076	.052	.085	.114	.049	.123	1.00	-
Child SCQ scores	.148	.037	-.166	-.221+	-.331**	-.480***	-.457***	-.459***	-.569***	-.707***	-.026	1.00

Note: Values outside of parentheses reflect Spearman's zero-order correlation coefficients. Values within parentheses reflect Spearman's partial correlation coefficients controlling for child age and child SCQ scores. $^{+}p < .10$, * $p \leq .05$, ** $p < .01$, *** $p \leq .001$. EC: expressive communication, MLU: mean length of utterance, NDW: number of different words, NTW: number of total words, RC: receptive communication, SCQ: social communication questionnaire, VABS: vineland adaptive behavior scales.

Table 3. Unstandardized parameter estimates for fully saturated structural equation model

	b	*SE*	*p*
Child age → annual household income	-.012	.025	.627
SCQ scores → annual household income	.073	.050	.146
Child age → parent education level	**-.052**	**.015**	**<.001**
SCQ scores → parent education level	.016	.027	.542
Annual household income → parent NTW	**1.978**	**.670**	**.003**
Parent education level → parent NTW	-2.028	1.436	.158
Child age → parent NTW	**-.397**	**.157**	**.012**
SCQ scores → parent NTW	-.436	.286	.127
Annual household income → parent NDW	**.436**	**.160**	**.006**
Parent education level → parent NDW	-.383	.281	.173
Child age → parent NDW	-.050	.030	.093
SCQ scores → parent NDW	**-.125**	**.060**	**.036**
Annual household income → parent MLU	**.078**	**.037**	**.036**
Parent education level → parent MLU	-.033	.068	.628
Child age → parent MLU	.005	.009	.601
SCQ scores → parent MLU	**-.042**	**.013**	**.001**
Annual household income → VABS EC scores	-.014	1.094	.990
Parent education level → VABS EC scores	2.046	1.355	.131
Child age → VABS EC scores	.140	.193	.468
SCQ scores → VABS EC scores	**-1.817**	**.432**	**<.001**
Parent NTW → VABS EC scores	-.198	.316	.530
Parent NDW → VABS EC scores	.958	1.824	.600
Parent MLU → VABS EC scores	**7.905**	**3.072**	**.010**
Annual household income → VABS RC scores	.341	.594	.566
Parent education level → VABS RC scores	1.303	.812	.108
Child age → VABS RC scores	.226	.126	.074
SCQ scores → VABS RC scores	**-1.582**	**.248**	**<.001**
Parent NTW → VABS RC scores	.025	.186	.891
Parent NDW → VABS RC scores	.115	1.103	.917
Parent MLU → VABS RC scores	1.169	2.071	.573

Note. Significant direct associations are in bold (*p*s<.05). EC: expressive communication, MLU: mean length of utterance, NDW: number of different words, NTW: number of total words, RC: receptive communication, SCQ: social communication questionnaire, VABS: vineland adaptive behavior scales.

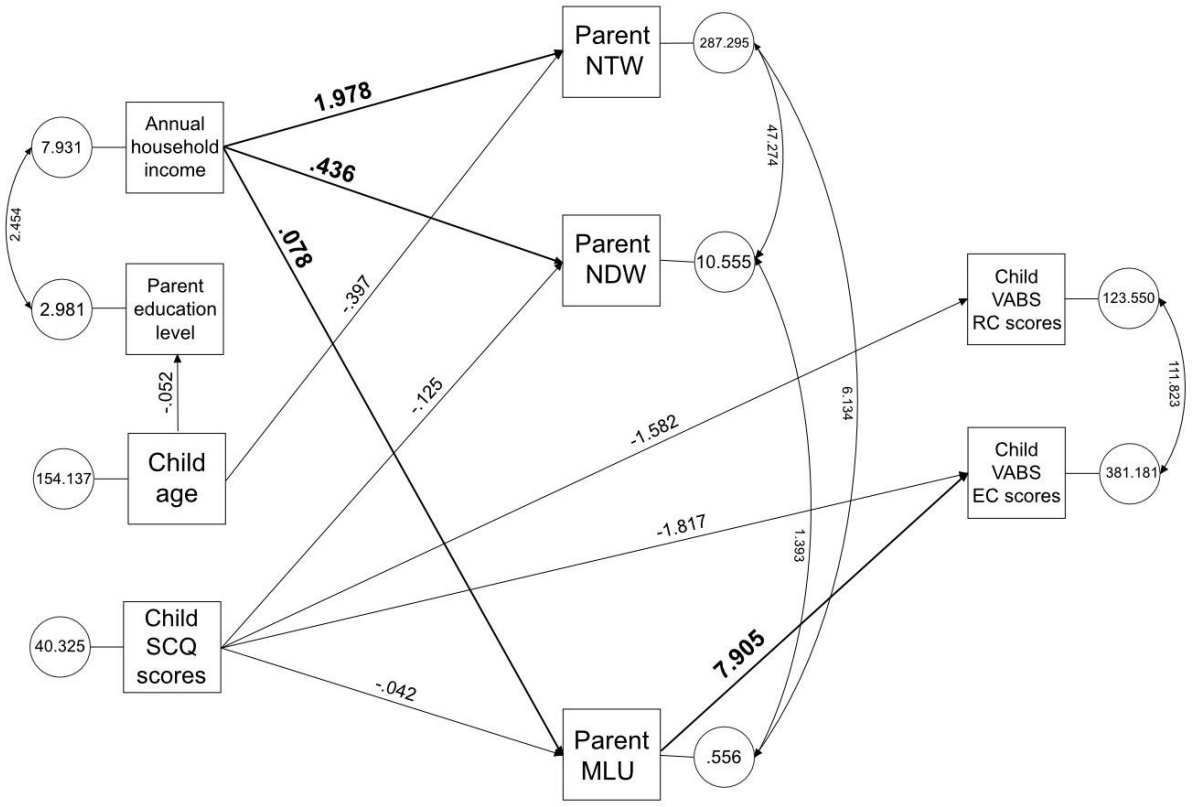

Figure 1. Unstandardized coefficients for significant direct associations between variables of interest are shown in bolded text. Unstandardized coefficients for significant associations between covariates and variables of interest are shown in non-bolded text. Covariances are also shown in non-bolded text. Residual variances are shown in non-bolded text within circles. EC: expressive communication, MLU: mean length of utterance, NDW: number of different words per minute, NTW: number of total words per minute. RC: receptive communication, SCQ: social communication questionnaire, VABS: vineland adaptive behavior scales.